US005742313A

United States Patent [19]

Hine

[11] Patent Number: 5,742,313

[45] Date of Patent: Apr. 21, 1998

[54] **EFFICIENT INK JET HEAD ARRANGEMENT**

[75] Inventor: **Nathan P. Hine**, South Strafford, Vt.

[73] Assignee: **Spectra, Inc.**, Hanover, N.H.

[21] Appl. No.: **331,921**

[22] Filed: **Oct. 31, 1994**

[51] **Int. Cl.**[6] **B41S 2/19**

[52] **U.S. Cl.** **347/92**

[58] **Field of Search** 347/88, 92, 87, 347/49

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,663,222	5/1987	Ohue et al.	428/224
4,788,556	11/1988	Hoisington+.	
4,814,786	3/1989	Hasington et al.	347/88
4,870,430	9/1989	Daggett et al.	347/88
4,940,995	7/1990	Hine et al. .	
5,013,339	5/1991	Mahoney et al.	210/500.23
5,049,904	9/1991	Nakamura et al.	347/49
5,182,581	1/1993	Kashimura et al.	347/87
5,189,438	2/1993	Hine et al.	347/92
5,208,610	5/1993	Su et al.	347/49
5,260,360	11/1993	Mrozinski et al.	524/95
5,276,468	1/1994	Deur et al.	347/88 X

FOREIGN PATENT DOCUMENTS

60-206658	10/1985	Japan	347/8
61-249760	11/1986	Japan	347/92

OTHER PUBLICATIONS

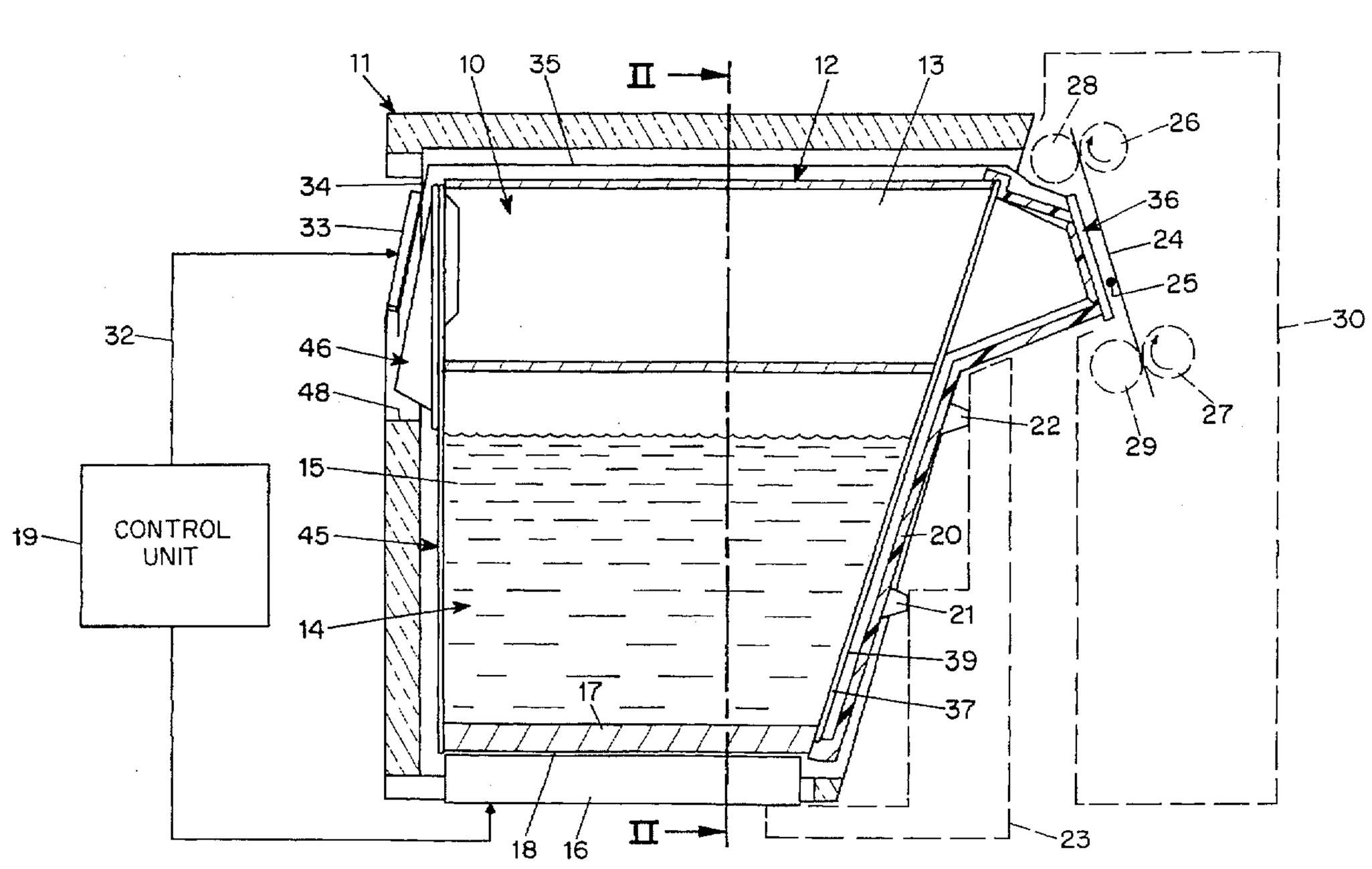
Soukhanov et al., Webster's II New Riverside University Dictionary, 1988, p. 999.

Primary Examiner—Benjamin R. Fuller
Assistant Examiner—Juanita Stephens
Attorney, Agent, or Firm—Brumbaugh, Graves, Donohue & Raymond

[57] **ABSTRACT**

In the ink jet head described in the specification, a reservoir body contains three ink reservoirs and a vacuum reservoir and a cover plate at the front of the reservoir body provides passages to supply ink from the ink reservoirs to an ink jet array from which ink is selectively ejected in response to electrical signals. Air-permeable, ink-impermeable membranes in a lung plate adjacent to the cover plate provide one wall of the ink passages, and the opposite sides of the membranes communicate with the vacuum reservoir. The reservoir body is made of a heat-conductive material and is removably received in an insulating housing containing a cartridge heater which supplies heat to the bottom of the reservoir body.

15 Claims, 4 Drawing Sheets



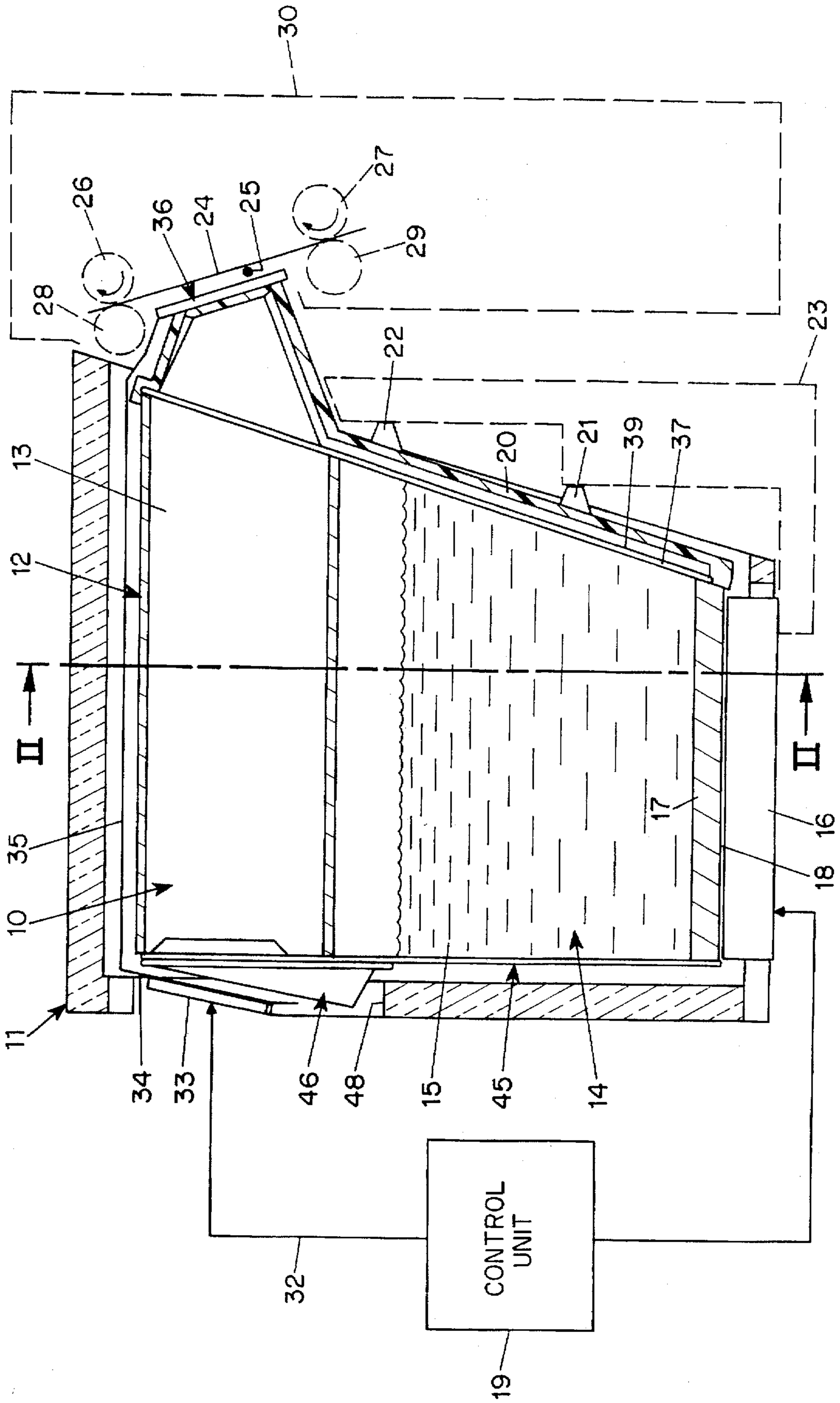

30
26
36
24
25
27
29
28
23
22
13
20
21
39
37
12
II
II
35
10
17
16
18
11
34
33
46
48
15
45
14
CONTROL UNIT
32
19

FIG. 1

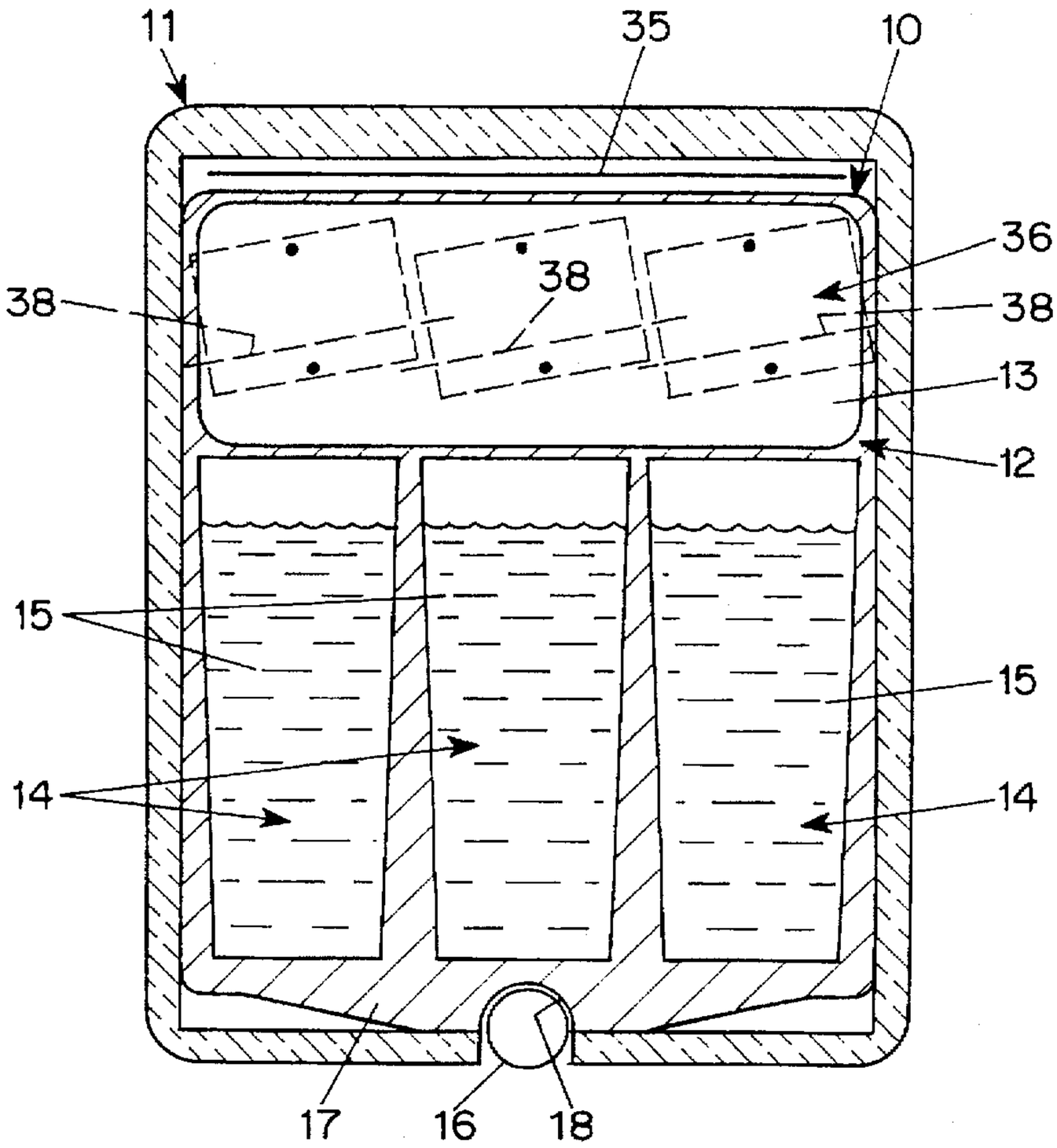

11
35
10
36
38
38
38
13
12
15
15
14
14
17
16
18

FIG. 2

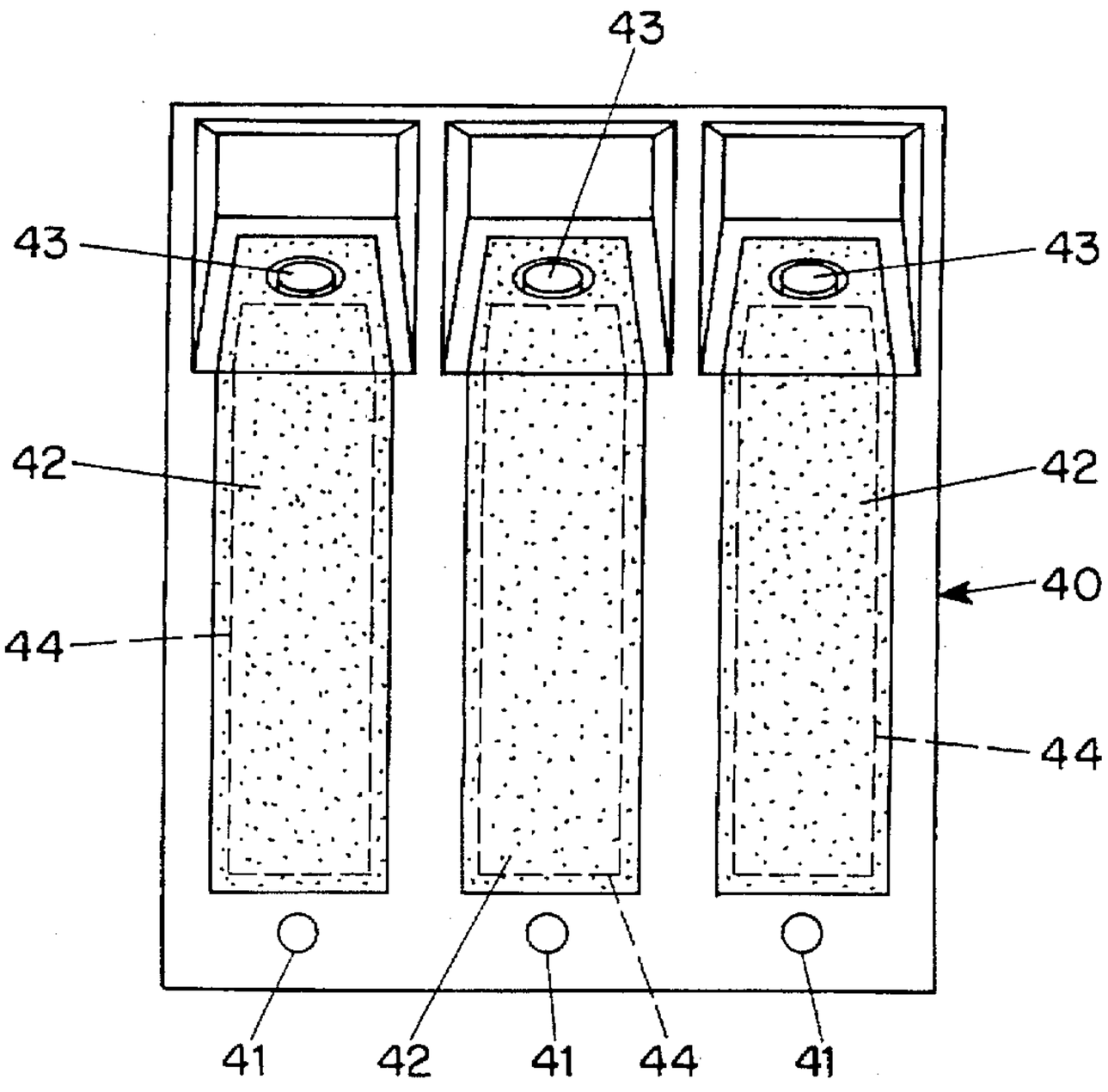

43
43
43
42
42
40
44
44
41
42
41
44
41

FIG. 3

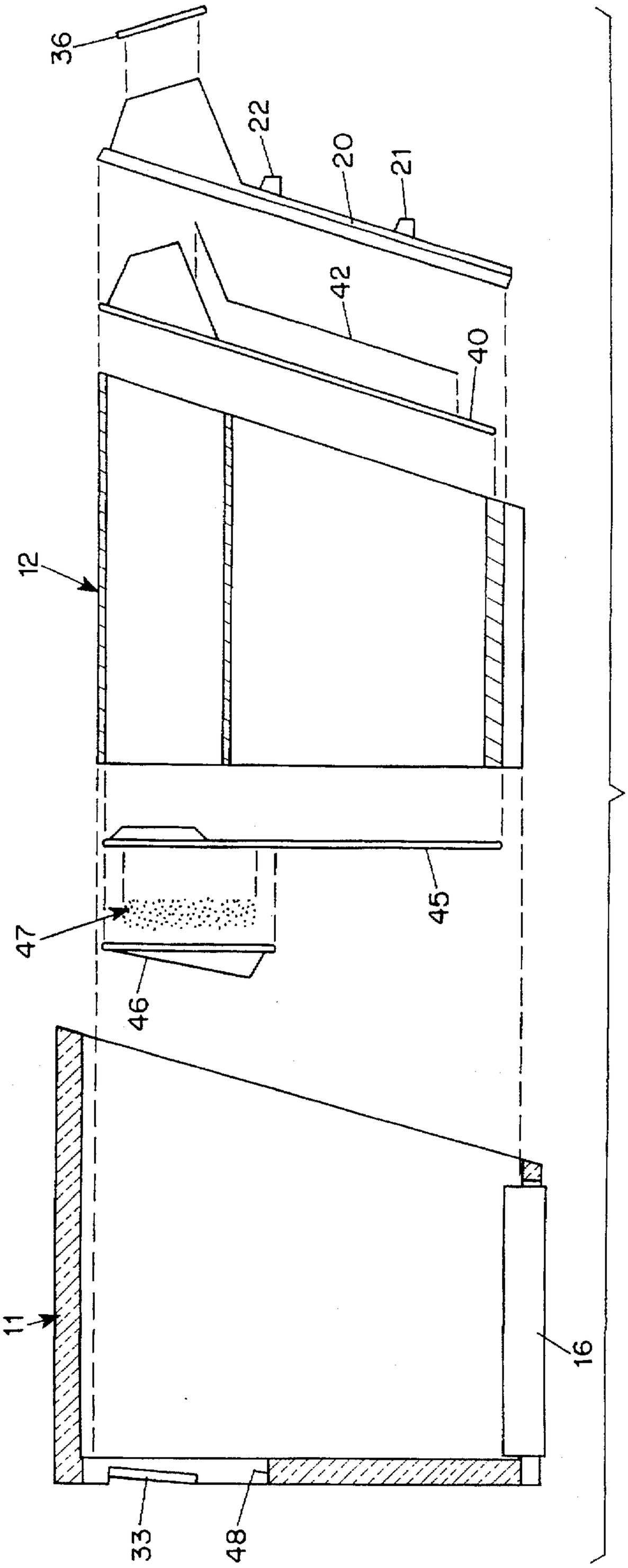


FIG. 4

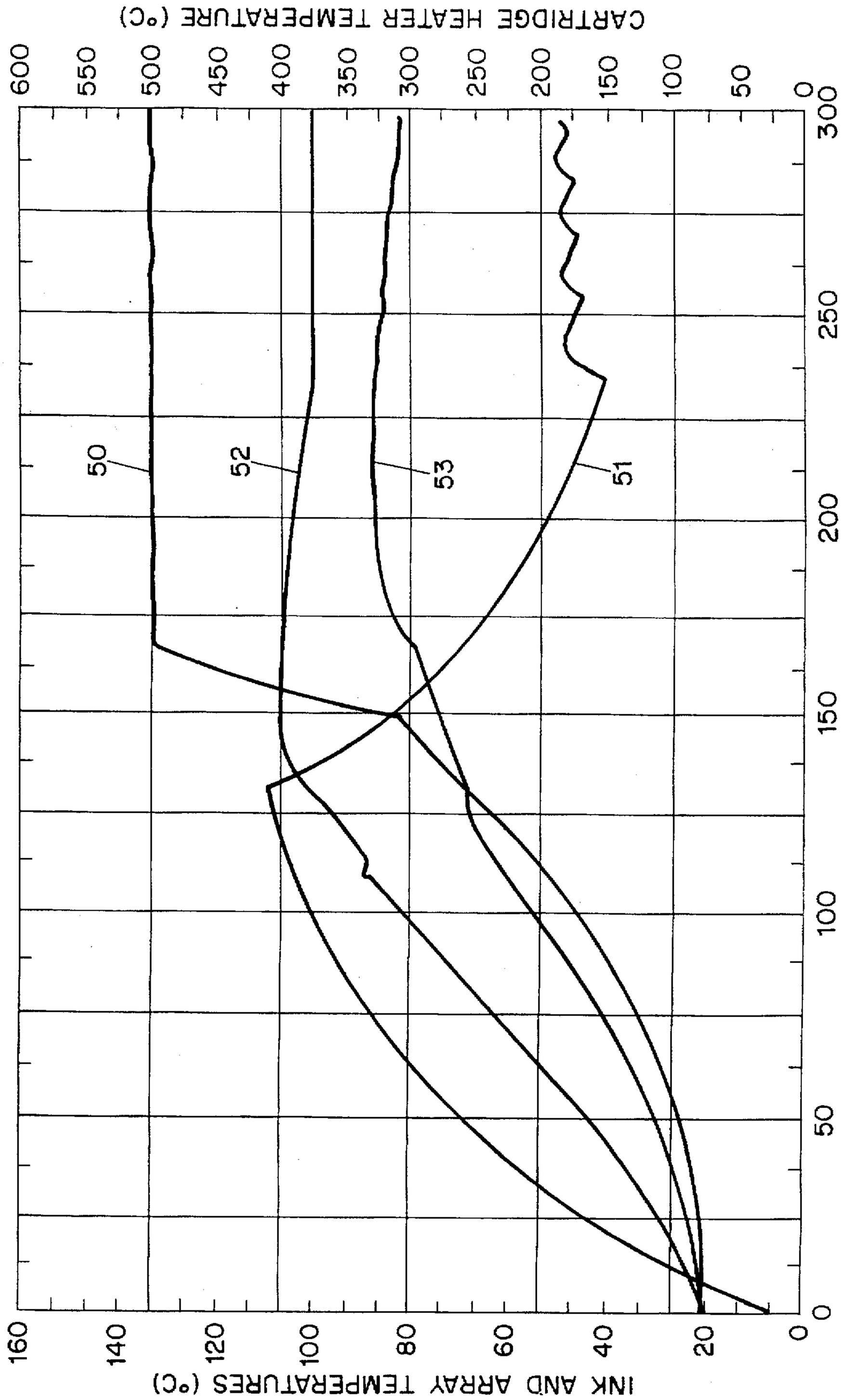

CARTRIDGE HEATER TEMPERATURE (°C)
600
550
500
450
400
350
300
250
200
150
100
50
0
300
250
200
150
100
50
TIME (SEC.)
50
52
53
51
160
140
120
100
80
60
40
20
0
INK AND ARRAY TEMPERATURES (°C)

FIG. 5

EFFICIENT INK JET HEAD ARRANGEMENT

BACKGROUND OF THE INVENTION

This invention relates to ink jet systems and, more particularly, to an ink jet head which is arranged to provide improved convenience and efficiency of operation.

Heretofore, ink jet heads, which are usually driven in a reciprocating motion adjacent to a substrate on which an image is produced by ink selectively ejected from the head, have been relatively large and cumbersome and often require remote stationary ink reservoirs from which ink is pumped periodically to the ink jet head. One such arrangement is disclosed in the Hoisington et al. U.S. Pat. No. 4,814,786 issued Mar. 21, 1989, the disclosure of which is incorporated herein by reference. Moreover, in ink jet systems in which dissolved air is removed from the ink by subjecting it to reduced pressure, as described, for example, in the Hoisington et al. U.S. Pat. No. 4,788,556 issued Nov. 29, 1988 and the Hine et al. U.S. Pat. No. 4,940,995 issued Jul. 10, 1990, the disclosures of which are incorporated herein by reference, a flexible line connected to a remote vacuum pump is required. More recently, in the copending Hine application Ser. No. 08/143,165 filed Oct. 26, 1993, the disclosure of which is incorporated herein by reference, a self-contained replaceable vacuum reservoir for an ink jet head is provided, and in the copending Hoisington application Ser. No. 08/143,166 filed Oct. 26, 1993, the disclosure of which is incorporated herein by reference, an ink jet head includes a replaceable ink reservoir.

Generally, such prior art arrangements have been bulky, making them inconvenient to assemble and use, relatively heavy, thereby requiring excessive power for acceleration during reciprocating motion, and relatively difficult to heat and maintain at a desired temperature for use with hot melt ink.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a new and improved ink jet head arrangement which overcomes the disadvantages of the prior art.

Another object of the invention is to provide an improved replaceable ink jet head arrangement having self-contained ink and vacuum reservoirs, providing improved convenience in manufacture and use and greater efficiency in operation.

These and other objects of the invention are attained by providing a housing and a reservoir body removably received in the housing and containing a plurality of ink reservoirs and a vacuum reservoir and an ink jet array containing a plurality of ink jet orifices and associated ink chambers supplied with ink by passages leading from the ink reservoirs, together with actuating elements for applying pressure to the pressure chambers to initiate ejection of ink drops through corresponding orifices. In order to remove dissolved air from the ink, which could interfere with the operation of the ink jet head, the passages leading from the ink reservoirs to the ink chambers are adjacent to a lung plate containing air-permeable, ink-impermeable membranes which communicate on one side with the ink in the passages and on the other side with the vacuum reservoir.

In one embodiment in which hot melt ink is provided, the housing is made of an insulating material having a cartridge heating element adjacent to the bottom wall of the reservoir body, which is made of a heat-conductive material such as metal, preferably aluminum. In addition, a separate heating element is provided in the ink jet array in order to maintain the ink at a desired controlled temperature when it is ejected.

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects and advantages of the invention will be apparent from a reading of the following description in conjunction with the accompanying drawings, in which:

FIG. **1** is a schematic view in longitudinal section of a representative embodiment of an ink jet head arrangement in accordance with the invention;

FIG. **2** is a cross-sectional view taken on the line II—II of FIG. **1** illustrating the arrangement of the reservoirs in the ink jet head;

FIG. **3** is a front view showing the lung plate of the ink jet head of FIG. **1** with lung membranes mounted in position;

FIG. **4** is an exploded side view illustrating the arrangement of the principal components of the representative embodiment of the ink jet head shown in FIG. **1**; and

FIG. **5** is a graphical representation illustrating the temperature characteristics of the ink jet head illustrated in FIGS. **1–4** when used with hot melt ink.

DESCRIPTION OF PREFERRED EMBODIMENT

In the representative embodiment of the invention illustrated in sectional view in FIG. **1**, an ink jet head **10** is removably mounted in a protective insulating housing **11**. As best seen in FIG. **2**, the ink jet head **10** includes a reservoir body **12** containing a vacuum reservoir **13** in its upper portion and a plurality of laterally-adjacent ink reservoirs **14** disposed in side-by-side relation beneath the vacuum reservoir **13**, each containing a supply of ink **15**, which may be of a different color in each reservoir. If the ink is hot melt ink, which is normally solid at room temperature and molten at elevated temperature, a cartridge heater **16** is mounted in the housing **11** so as to be received within a recess **18** in the bottom wall **17** of the reservoir body **12**. Power is supplied to the cartridge heater **16** from a control unit **19** so as to heat the ink reservoirs **14** to a temperature sufficient to melt the ink **15** in the reservoirs and then maintain the temperature of the ink in the reservoirs at a desired level.

The ink jet head **10** has a front cover **20** formed with positioning bosses **21** and **22** so as to position the ink jet head at a desired location in a carriage **23**, which is schematically illustrated in dotted outline, the carriage being arranged to move the head **10** in a reciprocating motion in the usual manner adjacent to a substrate **24** on which an image is to be printed by ink drops **25** projected from the ink jet head.

The substrate **24** is conveyed by drive rolls **26** and **27** and associated nip rolls **28** and **29** disposed within a conventional paper-handling system **30**, which is illustrated schematically in dotted outline in FIG. **1**. As will be understood by those skilled in the art, the ink jet head **10** is reciprocated perpendicular to the plane of FIG. **1**, and the substrate **24** is conveyed in a direction perpendicular to the reciprocating motion of the ink jet head **10** so that the selective ejection of ink drops **25** produces a desired image on the substrate.

For this purpose, the control unit **19** supplies signals through a line **32** to a contact pad **33** in the housing **11** which engages a contact area **34** of a flexible conductor strip **35** leading to an ink jet array **36** of the type disclosed, for example, in the copending Moynihan et al. application Ser. No. 08/215,301 filed Mar. 21, 1994, the disclosure of which is incorporated herein by reference. Ink from each of the

three reservoirs **14** is conveyed through corresponding passages **37** in the front cover **20** to the ink jet array **36** for selective ejection of ink drops through orifices in a series of orifice arrays **38**, illustrated schematically in dotted outlines in FIG. **2**, in accordance with signals transmitted to the ink jet array by the control unit **19** through the conductor strip **35**. Another heater **39** is provided in the ink jet array **36** to maintain the ink jet at a controlled temperature.

A lung plate **40**, mounted adjacent to the front cover **20**, has three apertures **41**, shown in FIG. **3**, through which ink from the corresponding reservoirs **14** passes to the side of the plate facing away from the reservoirs, after which it is conducted along the passages **37** formed in the cover **20**. Three air-permeable, ink-impermeable membrane members **42**, mounted on the lung plate **40**, form one wall of the passages **37** Which lead to openings **43** in the upper part of the plate **40** communicating with corresponding orifices in the orifice arrays **38** in the ink jet array **36** to supply ink thereto. The lung plate **40** also has passages **44**, shown in dotted outline in FIG. **3**, formed on the opposite sides of the membranes **42** which communicate with the vacuum reservoir **13** so that subatmospheric pressure is continuously maintained on the opposite sides of the membranes **42** with respect to the ink passages **37** leading from the openings **41** to the openings **43**. As a result, dissolved air contained in the ink **15** is continuously extracted from the ink as the ink passes from the reservoirs **14** to the ink chambers in the ink jet array **36**. This inhibits the formation of air bubbles in the ink jet array which could result from reduced pressure applied to the ink in the pressure chambers in the array during the ejection of ink drops, as described in the above-identified Hine application Ser. No. 08/143,165.

The reservoir body **12** of the ink jet head **10** also has a rear cover **45** formed with a filter enclosure **46** in which a filter member **47** (shown in FIG. **4**) is arranged to permit air to enter each of the reservoirs **14** as ink is withdrawn from them during operation of the ink jet head, a corresponding opening **48** being provided in the rear wall of the housing **11** to receive the rear cover **45**. To avoid escape of ink, the filter **47** is made of a material which is not wettable by the ink **15** and has pores which are small enough to prevent ink from flowing through them if the ink jet head **10** is tilted.

In a specific embodiment, the reservoir body **12** is an integral extruded-aluminum member shaped to provide three ink reservoirs **14**, each having an ink volume of about 18 cc, which is sufficient to produce about 1,300 printed pages, and a vacuum reservoir **13** having a volume of about 50 cc, and the area of each of the vacuum passages **44** exposing the membranes **42** to the reservoir vacuum is about 4 cm^2.

Preferably, the membranes **42** are made of polyvinylidene chloride sheet material from 2.5 to 25 μm thick, nylon sheet material from 25 to 250 μm thick, polytetrafluoroethylene sheet material from 10 to 100 μm thick or polypropylene sheet material from 25 to 250 μm thick, and are selected to provide a minimum deaeration effectiveness of about 20% at the end of a one-year shelf life or at the end of a 1,300-page ink reservoir printing life. With an initial reservoir vacuum level of about 0.1 atmosphere, this can be achieved using polyvinylidene chloride membranes approximately 13 μm thick, nylon membranes approximately 150 μm thick, polytetrafluoroethylene membranes approximately 38 μm thick, or polypropylene membranes approximately 150 μm thick. At the end of the reservoir shelf life or ink usage life, the vacuum reservoir pressure is about 0.25 atmosphere using the specified polyvinylidene chloride membranes and about 0.5 atmosphere using the other membranes having the specified thicknesses.

The exploded view of FIG. **4** illustrates the simple and convenient manner by which the ink jet head of the invention can be fabricated and assembled. In this illustration, the filter cover **46**, which may be a stamped aluminum piece, for example, is adhesively bonded to the rear cover **45** with the nonwettable vent filter **47** clamped between them, and the rear cover **45** is then adhesively bonded to the extruded aluminum reservoir body **12**. The lung membranes **42** are adhesively bonded to the front surface of the lung plate **40** in the manner shown in FIG. **3**, and the lung plate is then adhesively bonded to the front of the aluminum reservoir body **12** to provide communication between the vacuum passages **44** and the vacuum reservoir **13**. Thereafter, the front cover **20**, which may be molded from a rigid synthetic material, is adhesively bonded to the reservoir body **12** and to the lung plate **40**, and the ink jet array **36** of the type described, for example, in the copending application Ser. No. 08/215,301, is adhesively bonded to the front cover **20** and the lung plate **40** so that the ink passages **37** provide communication between the ink reservoirs **14** and appropriate passages in the ink jet array **36**, and the conductor strip **35** shown in FIGS. **1** and **2** is connected to appropriate terminals in the ink jet array. The completed assembly is then releasably locked into the protective housing **11**, into which the cartridge heater **16** and contact pad **33** have been mounted, so that the conductors in the contact area **34** of the conductor strip **35** engage appropriate contacts in the contact pad **33**.

FIG. **5** illustrates the temperature characteristics of an ink jet head of the type described above on start-up when used with a hot melt ink which melts at about 80° C. and is jetted at about 137° C. In the illustrated example, the heater in the ink jet array **36** is controlled by the control unit **19** to maintain the array temperature, represented by the line **50** and shown by the scale at the lefthand side of the graph, at about 137° C. At the same time, the cartridge heater temperature, represented by the line **51** and shown by the scale at the righthand side of the graph, is controlled to initially increase to a high temperature approaching 400° C. during the first two minutes of operation, and is then kept at a lower temperature below about 200° C. so as to maintain the temperature of the ink near the bottom of the reservoirs, represented by the line **52** and shown by the scale in the graph, at about 100° C. With this arrangement, the ink near the front wall of the ink reservoirs has a temperature, represented by the line **53** and shown in the lefthand scale in the graph, of about 85° C.

Thus, with the illustrated heater arrangement, the ink jet head **10** can be ready to operate within three minutes of the time when power is applied to the heaters.

Although the invention has been described herein with reference to a specific embodiment, many modifications and variations therein will readily occur to those skilled in the art. Accordingly, all such variations and modifications are included within the intended scope of the invention.

I claim:

1. An ink jet head arrangement comprising a reservoir body made of heat-conductive material containing a plurality of ink reservoirs and a vacuum reservoir, an ink jet array affixed to the reservoir body and arranged to eject ink drops selectively in response to electrical signals, and a lung plate interposed between the ink reservoirs in the reservoir body and the ink jet array having a plurality of air-permeable, ink-impermeable membranes, each membrane providing on one side one wall of one of a plurality of ink passages leading from the reservoirs to the ink jet array and each membrane communicating on another side of said mem-

brane with the vacuum reservoir so as to extract dissolved air from ink in the ink passages without requiring a connection to an external vacuum generator.

2. An ink jet head arrangement according to claim **1** including a holder for removably receiving the ink jet head, and positioning means on the ink jet head for positioning the ink jet head with respect to a substrate to which ink is to be applied from the ink jet head.

3. An ink jet head arrangement according to claim **2** wherein the reservoir body is made of metal and the holder is made of an insulating material and further comprising first heater means mounted in the holder for heating a bottom surface of the reservoir body and second heater means for heating the ink jet array to maintain hot melt ink contained in the reservoir and ejected from the array at desired temperatures.

4. An ink jet head arrangement according to claim **1** including a filter member disposed in one wall of the reservoir body and made of a material which is not wetted by ink contained in the reservoir body to permit air to enter an ink reservoir as ink is used without permitting ink to pass out of the reservoir through the filter member.

5. An ink jet head arrangement according to claim **1** wherein the air-permeable, ink-impermeable membranes are polyvinylidene chloride membranes having a thickness between 2.5 and 25 μm and wherein the vacuum reservoir has a pressure between about 0.1 and about 0.25 atmosphere.

6. An ink jet head arrangement according to claim **1** wherein the air-permeable, ink-impermeable membranes are made of nylon having a thickness between about 25 and about 250 μm and the vacuum reservoir has a pressure between about 0.1 and about 0.5 atmosphere.

7. An ink jet head arrangement according to claim **1** wherein the air-permeable, ink-impermeable membranes are made of polytetrafluoroethylene having a thickness between about 10 and about 100 μm and the vacuum reservoir has a pressure between about 0.1 and about 0.5 atmosphere.

8. An ink jet head arrangement according to claim **1** wherein the air-permeable, ink-impermeable membranes are made of polypropylene having a thickness between about 25 and 250 μm and the vacuum reservoir has a pressure between about 0.1 and about 0.5 atmosphere.

9. An ink jet head arrangement comprising a reservoir assembly including an extruded-aluminum reservoir body member having a plurality of separate compartments and front and rear wall members adhesively bonded thereto to provide a plurality of ink reservoirs for hot melt ink in a lower portion and a vacuum reservoir in an upper portion, an ink jet array adhesively bonded to the front wall member and arranged to selectively eject ink drops through orifices in response to corresponding electrical signals, the front wall member providing a plurality of ink passages to supply ink from the reservoirs to the ink jet array, and a lung plate mounted between the extruded-aluminum member and the front wall member having a plurality of membranes forming on one side one wall of each of the plurality of ink passages and each membrane communicating on an opposite side with the vacuum reservoir to extract dissolved air from ink passing through the ink passages.

10. An ink jet head arrangement according to claim **9** including a holder made of insulating material arranged to removably receive the reservoir body and including first heater means adjacent to a lower portion of the reservoir body for heating ink contained therein in a controlled manner, and further comprising second heater means in the ink jet array for maintaining the ink jet array at a controlled temperature, and air vent means in the reservoir body permitting air to enter each of the reservoirs as ink therein is used and including a porous member made of a material which is not wettable by the ink in the reservoirs.

11. An ink jet head arrangement according to claim **10** including a conductor strip connected to the ink jet array to provide signals thereto for controlling selective ejection of ink drops therefrom, and contact means in the holder to engage conductors in the conductor strip and supply signals thereto.

12. An ink jet head arrangement according to claim **11** including control means for supplying signals to the contact means to control selective ejection of ink drops by the ink jet array.

13. An ink jet head arrangement according to claim **12** wherein the control means controls the operation of the first and second heater means to maintain ink in the reservoirs and in the ink jet array at desired temperatures.

14. An ink jet head comprising an ink reservoir body, an ink jet array, an ink passage leading from the ink reservoir body to the ink jet array to supply ink thereto, a vacuum reservoir, and an air-permeable, ink-impermeable member forming a part of the ink passage and having on one side a surface exposed to ink in the passage and having on an opposite side a surface connected to the vacuum reservoir so as to extract dissolved air from ink in the ink passage without requiring a connection to an external vacuum generator.

15. An ink jet head according to claim **14** wherein the air-permeable, ink-impermeable member comprises a material selected from a group consisting of nylon, polytetrafluoroethylene, polypropylene and polyvinylidene chloride.

* * * * *